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PRINCIPAL INVESTIGATOR: Mark L. Ettenhofer, PhD

CONTRACTING ORGANIZATION: The Henry M. Jackson Foundation (HJF)
                                                6720A Rockledge Drive, Suite 100
                                                Bethesda, MD 20817-1834

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Mark Ettenhofer, PhD

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E-Mail: mark.ettenhofer@usuhs.edu

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Mark Ettenhofer, PhD
The Henry M. Jackson Foundation (HJF)
6720A Rockledge Drive, Suite 100
Bethesda, MD 20817-1834

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14. ABSTRACT

During the baseline POP (08 MAR 2014 – 07 MAR 2014), a number of personnel, including Research Associate A, Post-Doc A, and Software Engineer, were hired. USUHS IRB #1 and HRPO approvals were obtained for the pilot study. Cognitive efficacy tasks were developed, beta-tested, and revised. EEG and eye tracking equipment was set up and integrated, and study personnel received training on data collection procedures, including EEG, eye-tracking, and virtual reality driving simulator data acquisition. Data collection for the pilot study was initiated and preliminary analyses are currently under way. Based upon examination of performance and self-report data, the cognitive efficacy tasks appear to successfully discriminate between workload conditions. We have begun development of algorithms to analyze EEG data. Key milestones are behind schedule due to a late start, but we are attempting to make up this time through accelerated pilot testing. Carry-forward funds will be used to complete tasks initially scheduled for Year 1 but now scheduled for early Year 2. Protocol documents for the next (primary) phase of this study have been prepped and are currently being reviewed by collaborators before being submitted to USUHS IRB #1 and HRPO.

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Introduction

The objective of this project is to validate a combined EEG and eye tracking system aimed at assessing compromised cognitive function stemming from mild traumatic brain injury (mild TBI). Research suggests that the neural injuries resulting from mild TBI do not always produce observable performance deficits. However, subjective ratings suggest that the level of effort required to perform at a given level can be higher with mild TBI; associated neuroimaging data reveal a broader recruitment of cortical neurons to accomplish tasks in mild TBI relative to uninjured individuals [1-3]. The research described here combines information from two distinct physiological sensing approaches to make inferences about injury-related changes in cognitive function using measures that are sensitive to cognitive effort. The goal is to combine the expertise of academic, military, and industry researchers to create a practical and effective neurodiagnostic assessment tool that can be used in a broad range of contexts in which cognitive assessment is relevant. Validation of the integrated EEG and eye tracking system will include evaluation of the specificity and sensitivity of these measures based on characterizations of injury severity, performance on a neurocognitive test battery, and self-report measures of cognitive efficacy. We will also include functional magnetic resonance imagining (fMRI) and diffusion tensor imaging (DTI) to characterize the extent of functional cortical recruitment and white matter injury, respectively. The inclusion of fMRI and DTI will provide an objective basis for cross-validating the EEG and eye tracking system. Both the EEG and eye tracking data will be collected in the context of a dual-task experimental paradigm with visual target detection.

Body

During the baseline period of performance (03/08/2013 – 03/07/2014), most tasks were accomplished as outlined in the statement of work.

Hire and train research personnel. Personnel, including Jessica Kegel (Research Associate A), Ashley Safford (Post-Doc B), Lindsay Reinhardt (Research Associate B), and Hai Pan (Software Engineer – originally a consultant line item) were hired. Training was completed on data collection procedures including eye-tracking, virtual reality driving simulator, and EEG data acquisition.

Obtain IRB approvals. USU IRB #1 approval for the pilot study was received on December 17, 2013. HRPO approval for the pilot study was received January 31, 2014.

Develop cognitive efficacy tasks for VR, PC, and MRI environments. Two PC-CETs (N-back and Color Match) and one VR-CET (Coastal Route) have been developed and tested.

N-Back.
The n-back task features three difficulty levels that represent varying levels of cognitive workload. During the simple reaction time condition (SRT; low cognitive workload), participants must fixate on a cross in the center of the screen. After a period of time, the cross is replaced by one of three cues (directional arrow, mis-directional arrow, or no cue – the cross persists). After 200ms, a target (white circle) appears on the left or the right. Participants are instructed to shift their gaze to the target and press a button on the response box as quickly as possible. The choice reaction time condition (CRT; moderate cognitive workload) is similar to the SRT condition, except the targets appear on the left or right as blue or green circles. Participants must gaze at the target and press one button if the target is green and a different button if the target is blue. The 1-back condition (high cognitive workload) requires participants to remember the color of the last target that appeared (blue or green). When the next target appears, participants must gaze at the target and press a button based on the color of the previous target.

<u>Color Match.</u>
The Color Match task is a dual task that requires participants to perform a vigilance task and a target detection task simultaneously. Participants see a square in the center of the screen. When the task begins, the border of the square changes color and the participant must continually try to match the color of the border to the color of the inside of the square by pressing a button. While completing this task, the participant must also fixate on a cross that is overlaid on the center of the square. After a period of time, this cross is replaced by one of three cues (directional arrow, mis-directional arrow, or no cue – the cross persists). After 200ms, a target (white circle) will appear on the left or the right. Participants are instructed to temporarily shift their gaze to the target while continuing to adjust the color of the border of the square. Cognitive workload is manipulated by adjusting the rate at which the color of the border changes (slow = low cognitive workload, medium = moderate cognitive workload, fast = high cognitive workload).

<u>Coastal Route</u>
The Coastal Route task takes place in the virtual reality driving simulator. Participants are instructed to drive along a coastal highway while performing the target detection task. Participants must fixate on a cross in the center of the screen which is replaced by one of three cues (directional arrow, mis-directional arrow, or no cue – the cross persists). After 200ms, a target (white circle) will appear on the left or the right. Participants are instructed to shift their gaze to the target while trying to maintain lane position. Motor tracking (steering) difficulty is modulated by the speed of the vehicle.

Pilot test each of the cognitive efficacy tasks among 30 healthy control participants. Data collection for the pilot study began in March 2013 following acquisition of the EEG equipment and training by Honeywell personnel. Data collection is slightly behind schedule due to a late start, but we are attempting to make this time up through accelerated pilot testing. Preliminary analyses of performance and self-report data suggest that the cognitive efficacy tasks successfully discriminate between workload conditions. Graph 1 illustrates the increase in reaction time as the workload increased from low to high in the N-back task. Graph 2 illustrates the increased distance from the RGB value of the center square as workload increased from low to high in the Color Match task. Graphs 3 and 4 illustrate the increased distance from center lane position and the increase in swerving as the workload increased from low to high. The favorable pilot testing results obtained thus far provide additional confidence that time can be made up during the pilot testing process.

Please note that carry-forward funds will be used to complete tasks initially scheduled for Year 1 but now scheduled for early Year 2. Protocol documents for the next (primary) phase of this study have been prepped and are currently being reviewed by collaborators before being submitted to USUHS IRB #1 and HRPO.

Disseminate project plans at a scientific meeting. Project plans have not yet been disseminated at a scientific meeting. Dr. Ettenhofer will be attending the Arrowhead TBI conference in Mid-April, where he will present information related to the underlying technology and discuss ongoing research with military and civilian stakeholder.

Update DOD/TATRC representatives on progress at annual meeting. Updates to DOD/TATRC representatives have not been provided at an annual meeting. We await instructions from TATRC representatives regarding the appropriate timing for this meeting. If timing is flexible, the time period in between pilot and primary studies may be a desirable time to hold this meeting.

Key Research Accomplishments

- Study personnel hired
- USU IRB #1 and HRPO approvals received for pilot study
- Training on data collection procedures completed with study personnel
- Pilot study is under way
- Preliminary data analyses have begun
- Algorithms are in development for EEG and eye tracking analyses
- Protocol documents for the primary phase of the study are prepped and being reviewed by collaborators before being submitted to USU IRB #1 and HRPO

Reportable Outcomes

There are no reportable outcomes at this time.

Conclusions

Preliminary analyses suggest that the cognitive tasks (CETs) that will be used for integrated eye tracking and neural monitoring are able to successfully discriminate cognitive workload across difficulty levels. This provides a promising basis for the extraction of valuable data relevant to detecting cognitive efficacy after TBI. Additional data from the pilot study, including EEG and eye-tracking data collected in the near future, will support more detailed interpretations and implications.
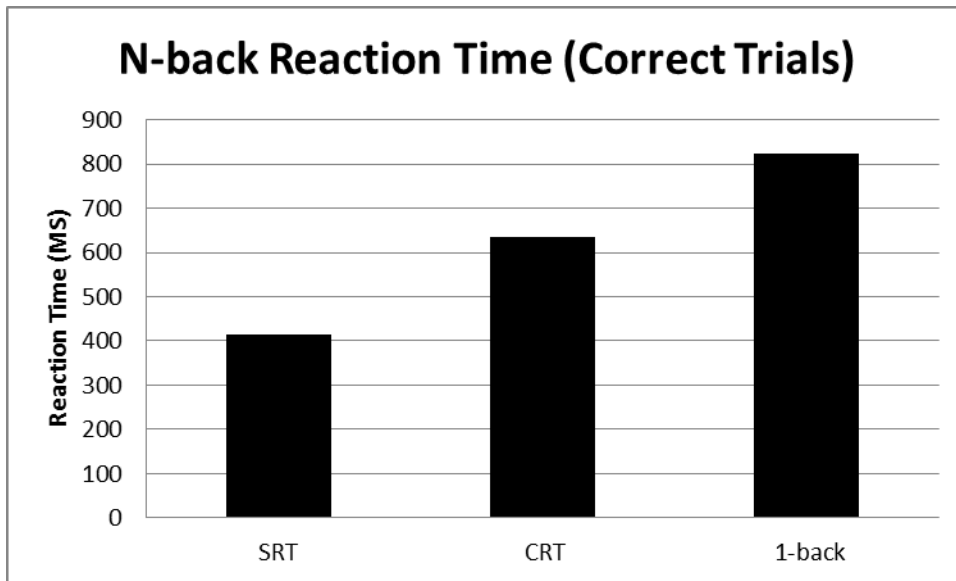
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2. Chen, J.K., et al., *Functional abnormalities in symptomatic concussed athletes: an fMRI study.* Neuroimage, 2004. **22**(1): p. 68-82.
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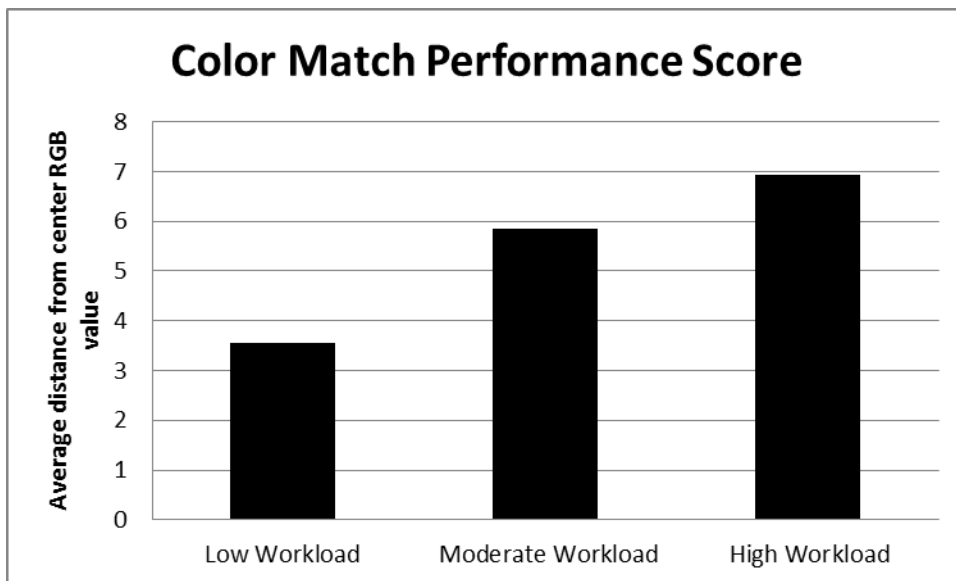
Appendices

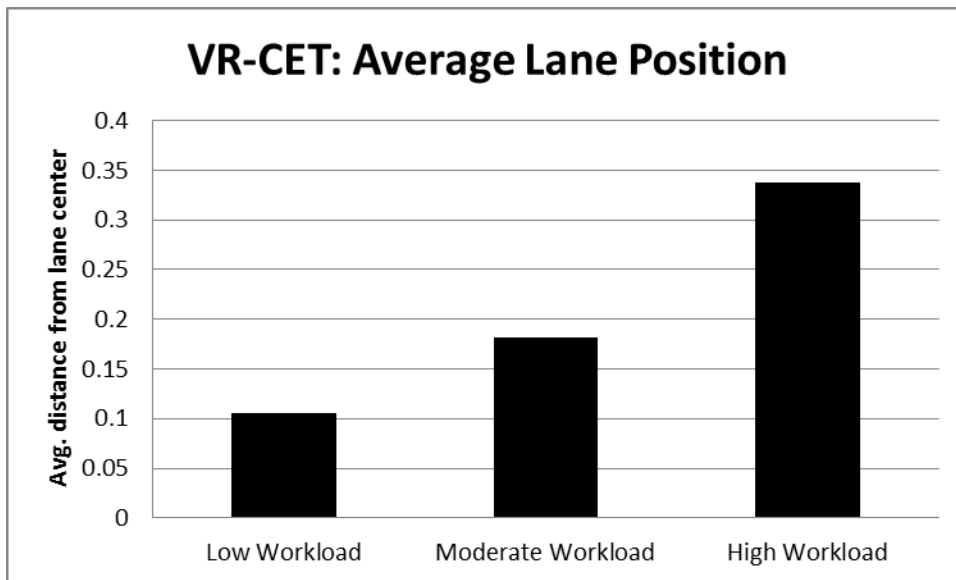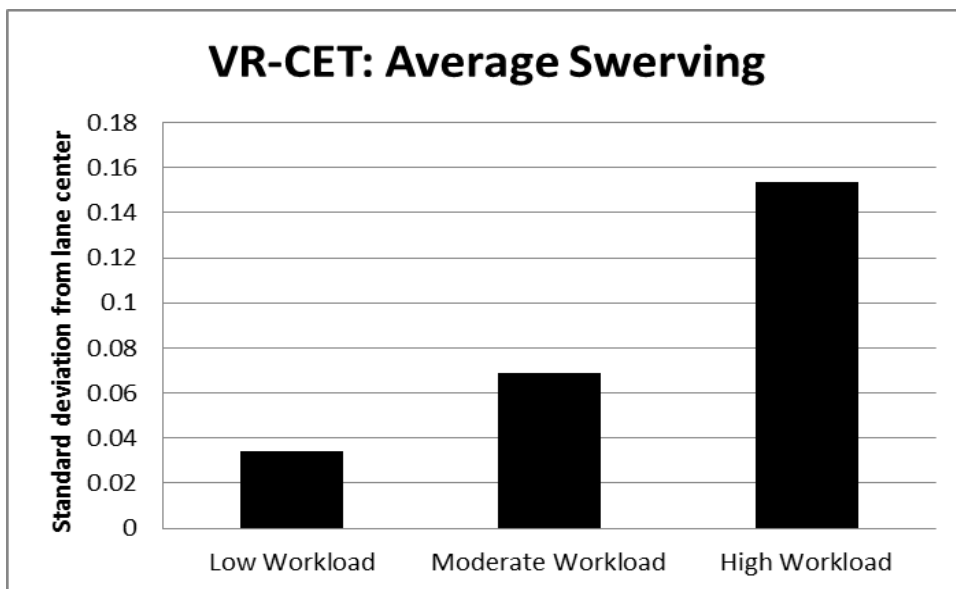There are no appendices for this report.

Supporting Data

N-back Reaction Time (Correct Trials)

Reaction Time (MS)

900
800
700
600
500
400
300
200
100
0

SRT   CRT   1-back

Graph 1

Color Match Performance Score

Average distance from center RGB value

8
7
6
5
4
3
2
1
0

Low Workload   Moderate Workload   High Workload

Graph 2

VR-CET: Average Lane Position

Graph 3

VR-CET: Average Swerving

Graph 4